UNIVERSITI PUTRA MALAYSIA

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By

WIJOPRIONO

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements For the Degree of Doctor of Philosophy

January 2006

DEDICATION

This thesis is dedicated to my beloved parents, wife, and daughter:

Djamin Sastro Suwito and late Widjiati;

Dwi Irianingsih, Siswoyo Budi Priono, Jodi Azhar Priono and Kemala Adi Citra

Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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January 2006

Chairman : Professor Kamaruzaman Jusoff, PhD

Faculty : Forestry

Pelagic fishery in the Java Sea is multi-species and dominated by a community of small pelagic species. This study attempted to employ different sources of data in order to determine the distribution of pelagic fish species and to estimate their environmental preferences. Catch per unit effort (CPUE), hydro-acoustic, satellite derived sea surface temperature (SST) and chlorophyll-a data as well as oceanographic *in situ* measurements data were used to achieve these objectives. CPUE data were collected from commercial fishing records available at the fishing port of Pekalongan, the main pelagic fish landing centre in the north coast of Java. Hydro-acoustic and oceanographic *in situ* measurements data were collected from hydro-acoustic survey carried out during September-October 2002, while the data of satellite derived SST of AVHRR-NOAA and chlorophyll-a derived from SeaWiFS were collected from the HRPT (High Resolution Picture Transmission) ground receiving station at BPPT (Assessment and Application of Technology Board), Jakarta, and GSFC-NASA (Goddard Space and Flight Center of the National Aeronautics and Space Administration). Correlation analysis, cluster analysis, PCA, spatial analysis and GIS technique were employed in determining abundance and

density distribution of pelagic fish species. Spatial analysis and GIS technique together with GLM were also applied in building the fishery-environment dependent model in order to estimate the environmental preferences of the fishes. Results of the study showed that the Java Sea water was seasonally occupied by oceanic water of the Indonesian Throughflow (ITF). The influence of the ITF was most pronounced in the southeast monsoon when the currents in the Java Sea flow towards the west. The influence is minimum in the northwest monsoon when the currents flow towards the east. The sea has a great thermal stability with a monthly SST average of 28.9 ^{0}C and the difference between maximum and minimum (gradient) of 2.0-3.5 ^{0}C. The abundance of phytoplankton tends to increase towards the west and towards the coastal areas off north coast of Java, south coast of Kalimantan, and around the small islands spreading over the Java Sea. Correlations between physical and biological oceanographic parameters were exhibited. Pelagic fishery resources in the Java Sea have undergone considerable variations in both their seasonal distributions and abundances. They were relatively low during northwest monsoon (December-March), and increased during southeast monsoon (June-September), with a peak at the end of the monsoon. Abundance of the resources was mostly driven by fluctuations in the abundance of one dominant species, *Sardinella* spp in the inshore and *Decapterus* spp in the offshore. The two species make up the average of 36% and 32% of the total CPUE, respectively. GLM model gave evidence that the pelagic fish species have a tolerance limit of temperature of up to 28.5 ^{0}C, and below this temperature limit they show a positive trend of relationships with chlorophyll-a concentrations. The model also revealed that oceanographic variables (SST and chlorophyll-a concentrations) contributed 54% to the total variance explained by the GLM predictors, confirming the relative importance of these variables in predicting

pelagic fish catch. However, relationship between sea surface temperature and chlorophyll-a concentrations was weak. The GIS model has demonstrated its capability in delineating spatial patterns of fish density in relation to the environmental variables, especially zooplankton, which was not covered in the GLM model.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

TABURAN SPESIES IKAN PELAGIK DI LAUT JAWA DARI DATA PENDERIAAN JAUH

Oleh

WIJOPRIONO

Januari 2006

Pengerusi : Profesor Kamaruzaman Jusoff, PhD

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Perikanan pelagik di Laut Jawa adalah multi-spesies dan dikuasai oleh komuniti spesies ikan pelagik kecil. Kajian ini menggunakan pelbagai sumber data yang berbeza bagi memastikan penyebaran spesies ikan pelagik dan menganggarkan keutamaan persekitaran mereka. Data hasil tangkapan per unit daya (CPUE), hidro-akustik, suhu permukaan laut (SST) dan klorofil-a daripada satelit, dan data oseanografi daripada pengukuran *in situ* digunakan bagi mencapai objektif kajian. Data CPUE diperolehi daripada rekod hasil tangkapan ikan komersil yang di Pelabuhan Perikanan Nusantara Pekalongan, iaitu pusat pendaratan ikan pelagik utama di pantai utara Jawa. Data hidro-akustik dan data oseanografi berdasar kepada pengukuran *in situ* diperolehi daripada hasil kajian hidro-akuatik yang dilaksanakan pada bulan September-Oktober 2002, manakala data SST dan klorofil-a daripada AVHRR-NOAA dan SeaWiFS diperolehi daripada stesen penerima resolusi tinggi (HRPT) Badan Pengkajian dan Penerapan Teknology (BPPT), Jakarta, dan GSFC-NASA (Goddard Space and Flight Center of the National Aeronautics and Space Administration). Analisis korelasi, analisis kelompok, PCA, analisis ruang dan teknik GIS (geographic information system) digunakan bagi memastikan kelimpahan dan

kepadatan taburan spesies ikan pelagik. Analisis spasial dan teknik GIS, dan juga GLM (general linear model) digunakan dalam membangunkan model antara perikanan dan persekitaran bagi memperkirakan keutamaan persekitaran daripada ikan-ikan pelagik. Hasil kajian menunjukkan bahawa Laut Jawa secara bermusim dipenuhi oleh air lautan yang dibawa oleh arus ITF (Indonesian Througflow). Pengaruh daripada ITF lebih ketara pada musim tengkujuh tenggara ketika arus-arus di Laut Jawa mengalir ke arah barat Pengaruhnya adalah minimum pada musim tengkujuh barat laut ketika arus di Laut Jawa mengalir ke arah timur. Laut ini mempunyai stabilan termal yang tinggi dengan purata bulanan SST 28.9 ^{0}C dan perbezaan antara gradient maksimum dan minimum adalah 2.0-3.5 ^{0}C. Kelimpahan fitoplankton cenderung untuk meningkat ke arah kawasan pantai barat dan kawasan-kawasan di luar pantai utara Jawa, pantai selatan Kalimantan, dan kawasan di sekitar pulau-pulau kecil yang terhampar di Laut Jawa. Korelasi di antara beberapa parameter-parameter oseanografi fizikal dan biologi ditunjukkan. Sumber-sumber perikanan pelagik di Laut Jawa mengalami perbezaan distribusi dan kelimpahan mengikut musim. Secara relatifnya, sumber ikan ini adalah rendah pada waktu musim tengkujuh barat laut (Disember-Mac), dan bertambah pada musim tengkujuh tenggara (Jun-September), dengan puncaknya pada penghujung musim tersebut. Kelimpahan sumber ini pada keseluruhannya berpunca daripada turun naiknya kelimpahan spesies utamanya, iaitu *Sardinella* spp di kawasan perairan pantai dan *Decapterus* spp di kawasan perairan dalam. Kedua-dua spesies ini membentuk masing-masing dengan purata 36% dan 32% daripada jumlah CPUE. Model GLM memberikan bukti bahawa spesies ikan pelagik memiliki had toleransi suhu sehingga 28.5 ^{0}C dan ikan-ikan pada suhu yang lebih rendah daripada ini menunjukkan hubungan positif dengan klorofil-a. Model tersebut juga mengungkap bahawa

pembolehubah-pembolehubah oseanografi (SST dan klorofil-a) menyumbang 54% kepada keragaman yang boleh diterangkan oleh pembolehubah-pembolehubah bebas dalam GLM, mengesahkan pentingnya pembolehubah-pembolehubah oseanografi tersebut dalam meramalkan tangkapan ikan pelagik. Walau bagaimanapun, perhubungan antara SST dan pemusatan-pemusatan klorofil-a adalah lemah. Model GIS menunjukkan kemampuannya bagi menggambarkan pola ruang bagi kepadatan ikan berhubung dengan pembolehubah persekitaran, terutamanya zooplankton, yang tidak dimasukkan dalam model GLM.

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I certify that an Examination Committee met on 19 January 2006 to conduct the final examination of Wijopriono on his Doctor of Philosophy thesis entitled "Distribution of Pelagic Fish Species in the Java Sea from Remote Sensing Data" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

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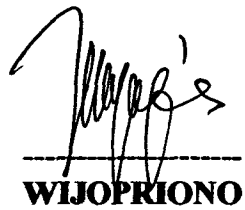
Date: 13 APR 2006

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



WIJOPRIONO

Date: 20/3/2006

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LIST OF ABBREVIATIONS

ACS	Attitude Control System
ADEOS	Advanced Earth Observation Satellite
AVHRR	Advanced Very High Resolution Radiometer
BURS	Bradford University Remote Sensing
C	Celsius
CDA	Command and Data Acquisition
CDOM	Colored Dissolved Organic Matter
CPUE	Catch per Unit Effort
CRISP	Centre for Remote Imaging, Sensing and Processing
CSIRO	Commonwealth Scientific and Industrial Research Organization
CTD	Conductivity Temperature Depth
CZCS	Coastal Zone Color Scanner
EMR	Electromagnetic Radiation
ESDU	Elementary Sampling Distance Unit
FAD's	Fish Aggregating Devices
GAC	Global Area Coverage
GIS	Geographic Information System
GLI	Global Imager
GLM	General Linier Model
GNP	Gross National Product
GOSSTCOMP	Global Operational Sea Surface Temperature Composite
GPS	Global Positioning System
GRT	Gross Registered Tonnage

GSFC	Goddard Space Flight Center
HRPT	High Resolution Picture Transmission
ITCZ	Inter-Tropical Convergence Zone
ITF	Indonesian Throughflow
JPL	Jet Propulsion Laboratory
LAC	Local Are Coverage
l_c	Length at first capture
l_m	Length at first maturity
m	Meter
MCSST	Multi-channel Sea Surface Temperature
MERIS	Medium Resolution Imaging Spectrometer
mg	Milligram
MODAS	Modular Data Assimilation System
MODIS	Moderate Resolution Imaging Spectroradiometer
MSY	Maximum Sustainable Yield
NASA	National Aeronautics and Space Administration
NIR	Near Infrared
nm	Nautical Mile
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
NW	Northwest
OCTS	Ocean Color and Temperature Scanner
p	Probability
PCA	Principal Component Analysis
PODAAC	Physical Oceanography Data Active Archive Center

POES	Polar-orbiting Operational Environmental Satellite
R/V	Research Vessel
SE	Southeast
SeaDAS	SeaWiFS Data Analysis System
SeaWiFS	Sea-Viewing Wide Field of View Sensor
SSH	Sea Surface Height
SST	Sea Surface Temperature
ST	Station
TAC	Total Allowable Catch
TS	Target Strength
TVG	Time Varied Gain